"Express Mail" Mailing Label No. EL 563 650 350 US

Date of Deposit August 16, 2000

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. § 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Dave Glisson
Typed or Printed Name of Person Mailing Paper or Fee

Dave Glisson
Signature of Person Mailing Paper or Fee

Atty Docket No. BEAR-006

PATENT APPLICATION

INTEGRIN BINDING MOTIF CONTAINING PEPTIDES AND METHODS OF TREATING SKELETAL DISEASES

Karl Bozicevic
Registration No. 28,807
BOZICEVIC, FIELD & FRANCIS LLP
200 Middlefield Road, Suite 200
Menlo Park, CA 94025

F:\DOCUMENT\BEAR (formerly 8302)\006\BEAR-006 - appln cover page.wpd

INTEGRIN BINDING MOTIF CONTAINING PEPTIDES AND METHODS OF TREATING SKELETAL DISEASES

TECHNICAL FIELD

The invention relates generally to the field of peptides and more particularly to peptides and formulations thereof useful in treating skeletal diseases.

BACKGROUND OF THE INVENTION

It is well-documented that disorders of skeletal tissues and mineral metabolism cause numerous significant health problems on world-wide basis.

In humans, the maximum bone mass occurs between the age of 15 and 40 and is referred to as "peak bone mass." After such peak bone mass age, bone mass begins declining gradually and the mechanical strength of the bone is accordingly reduced. Consequently, when mechanical strength declines to a certain level, the individual is at greater risk of bone fracture. This natural occurrence is called osteoporosis if severe enough to be pathogenic.

The speed at which bone loss occurs differs among individuals, and especially with respect to gender. In females, the speed of bone loss accelerates immediately after menopause (See Figure 1) because of a significant decline in available estrogen, a hormone which plays a critical role in maintaining healthy bone metabolism. Postmenopausal osteoporosis constitutes an important clinical problem because it afflicts significant numbers of women. Notably, the ratio of female to male osteoporosis patients is 3:1.

The majority of bone diseases are characterized by loss of bone minerals, weakening of bones and consequently, an increase of the frequency and severity of bone fractures, which are called "pathological fracture." In the elderly population, this has significant social ramifications as well, as many of those with bone fractures have difficulty with mobility, which often leads to the deterioration of other mental and physical functions, resulting in dementia, muscular weakness and/or fatigue. In addition, morbidity and pain are

significantly increased by thrombotic events, such as pulmonary embolism which occur as a result of hip or pelvic fractures.

In the United States alone, it is said that 52 million women over age of 45 will suffer from osteoporosis by 2000. Current worldwide osteoporosis population is around 200 million. Annual incidence of pathological fracture in the United States alone is approximately 1.5 million. It is estimated that annual medical costs for those osteoporosis patients in the United States and world are $14 billion and $60 billion, respectively.

Renal failure is also a significant health problem related to mineral metabolism and skeletal formation, and the number of its patients is increasing rapidly. Renal function is declining gradually over several to ten years period in these patients. When the renal function becomes approximately a quarter (1/4) of the healthy level, the patients are classified to chronic renal failure. When it becomes approximately one sixth (1/6) thereof, they need to start dialysis and are called end stage renal disease (ESRD). In patients with chronic renal failure, serum levels of important minerals such as calcium and phosphate lose their normal homeostasis, which results in malformation of skeleton. It is called renal osteodystropny (ROD), which is a secondary osteoporosis from renal failure. ROD can also cause pathological fracture like osteoporosis. The prevalence of end stage renal disease (ESRD) in the United States is rapidly increasing and about to reach 300 thousand in 2000. As ESRD is a part of chronic renal failure, there should be much higher number of ROD patients.

There are several other diseases of skeletal tissues and mineral metabolism such as Paget's Disease, rikets, osteopetrosis, hyperparathyroidism, and so forth and number of patients are affected by these diseases.

Metabolically, bone is a highly active organ with bone resorption and formation occurring continuously (remodeling). Bone resorption is facilitated by osteoclasts which are differentiated from monocyte/macrophage lineage cells. Osteoclasts adhere to the surface of bone and degrade bone tissue by secreting acids and enzymes. Osteoblasts facilitate bone formation by adhering to degraded bone tissue and secreting bone matrix proteins, which are mineralized mostly by calcium and phosphate. Osteoblasts differentiate into bone cells (osteocytes), and become a part of bone tissue.

Numerous experimental approaches have been attempted to either accelerate bone formation or diminish bone resorption. For example, growth factors such as BMPs (bone morphogenetic proteins), TGFβ (transforming growth factor β), IGF (insulin-like growth factor), fibroblast growth factor (FGF) are known to have potent biological activities in bone formation. In particular, a few subfamily molecules of BMP such as BMP-2 are regarded one of the most potent growth factors for hard tissue. However, these factors have not been developed as therapeutic agents for systemic bone diseases. It is because none of them can be delivered to the bone selectively and some of these factors such as BMPs convert soft tissue into hard tissue. It is called ectopic calcification and a critical adverse effect for them when they are used systemically. Further, the processes of bone formation and resorption are so closely connected and that makes selective increase of bone formation or selective inhibition of bone resorption extremely difficult.

Currently, there is a need for an effective treatment for bone loss. Therapeutic agents such as estrogen, calcitonin, vitamin D, fluoride, Iprifravon, bisphosphonates, and a few others have failed to provide a satisfactory means of treatment. (Gennari et al., Drug Saf. (1994) 11(3):179-95).

Estrogen and its analogues are frequently administered to patients with postmenopausal osteoporosis. Estrogen replacement therapy involves administration of estrogen just prior to or after the onset of menopause. However, as is often the case with steroid hormones, the long term use of estrogen has significant adverse effects such as breast and other gynecological cancers (Schneider et al., Int. J. Fertil. Menopausal Study (1995) 40(1):40-53).

Calcitonin, an endogenous hormone produced by the thyroid, binds selectively to osteoclasts, via its receptor, and inactivates them. Since the osteoclast is the only cell which can dissolve bone tissue, calcitonin binding can block or slow down bone degradation caused by the osteoclast. However, this biological mechanism is very short-lived, as the osteoclasts become tolerant to this drug relatively quickly. Therefore, the use of calcitonin does not provide an effective therapeutic option.

Fluoride has been shown to increase bone mass when it is administered to humans. However, while bone mass is increased, mechanical strength is not. Therefore, despite the increase in apparent bone mass, the risk of fracture remains (Fratzl et al., J. Bone Mineral Res. (1994) 9(10):1541-1549). In addition, fluoride administration has significant health risks.

Iprifravon has been used to treat osteoporosis in limited areas in the world. However, the actual efficacy of this compound is questionable and it is not widely accepted as a useful therapeutic agent for bone diseases.

Bisphosphonates are compounds derivatized from pyrophosphate. Synthesis involves replacing an oxygen atom situated between two phosphorus atoms with carbon and modifying the carbon with various substituents. While bisphosphonates are known to suppress bone resorption, they have little effect on bone formation. Furthermore, bisphosphonates adhere to the bone surface and remain there for very long time causing a long-term decrease in bone tissue turnover. As bone tissue needs to be turned over continuously, this decrease in turnover ultimately results in bone deterioration (Lufkin et al., Osteoporos. Int. (1994) 4(6):320-322; Chapparel et al., J. Bone Miner. Res. (1995) 10(1):112-118).

Another significant problem with the agents described above is that with the exception of fluoride and iprifravon, they are unsuitable for oral administration, and thus, must be given parenterally. Since bone disorders are often chronic and require long-term therapy, it is important that therapeutic agents be suitable for oral administration.

In summary, a significant need exists for a therapeutic agent which can prevent or treat bone loss. In particular, a new drug that can selectively increase bone formation and/or number of osteoblast without affecting bone resorption or soft tissue is highly desired.

Another major health problem relating to skeleton and mineral metabolism is that with teeth. In the United States alone, it is estimated that 67 million people are affected by periodontal disease and that the annual cost of its treatment is approximately $6.0 billion in 2000. It is said 90% of the entire population experience dental caries in their lives. The annual cost to treat them is over $50 billion per year in the United States alone.

Dental caries is a universal disease and affects children and adults. Periodontal disease, on the other hand, affects mostly adults, and in particular, the aged. In many cases, the patient's gum is inflamed and destroyed, the alveolar bone that supports the teeth is deteriorated. Cement that composes the core of the root is also damaged, and subsequently, teeth fall out. One of the most common treatments for tooth loss involves the use of a dental implant. An artificial implant (osseointegrated dental implants) is placed in the space where the tooth was lost. In severe cases, an entire denture is replaced by implants. However, implants frequently loosen, or fall out because their fixation on the alveolar bone is not always successful. Since alveolar bone is somehow damaged in these patients, the implant can not

always be supported well by alveolar bone. When alveolar bone is severely damaged, autogenous bone grafting is made. In this case, a bone graft taken from another skeletal tissue of the same patient is grafted in the damaged alveolar area so that the hard tissue is regenerated and sinus is elevated there. Since these treatments require expensive bio-compatible materials and/or highly skilled techniques, the cost of treatment is usually very high.

It is believed that dental caries is caused by acidic condition in the oral cavity. For instance, sugars are converted to acid and dissolve the surface of the teeth. Although only enamel and a part of dentin is affected in many cases, the damage can reach the pulp cavity in severe cases that cause significant pain. The most typical treatment is filling the caries lesion with undegradable materials such as metals or metal oxide. Treatment of dental caries mostly depends upon those materials and the techniques by the dentists, which is often expensive.

Although a few therapeutic agents have been developed and used in dental area, they are generally only anti-inflammatory drugs, analgesics, and antibiotics. No generally effective therapeutic agent that directly improves periodontal hard tissues has been developed. Obviously, there is a significant demand for a therapeutic agent that promotes regeneration of alveolar bone and/or teeth, and increases the number and activity of odontoblasts/osteoblasts that help form of dental tissues.

SUMMARY OF THE INVENTION

A class of compounds are disclosed which are useful in treating or preventing a condition associated with skeletal loss or weakness. The compounds are peptides or analogs thereof which comprise between 10 and 50 monomer (e.g. amino acids) units. The amino acid sequence comprises an integrin binding motif sequence which may be in the D- or L-conformation. The remaining monomer units (the sequence other than the integrin binding motif) in the compound may be amino acid analogs but are preferably naturally occurring amino acids having a sequence which is substantially the same as an amino acid sequence contiguous with the RGD sequence in the naturally occurring protein, matrix extracellular phosphoglycoprotein (Rowe et. al., Genomics (2000) 67:56-68).

An aspect of the invention is a set of peptides and/or peptide analogs.

A feature of the invention is that a compound of the invention comprised an integrin binding motif sequence in a D or L conformation.

09654037.081500

An advantage of the invention is that a compound of the invention enhances skeletal growth.

Another advantage of the invention is that a compound of the invention enhances the amount of osteoblast and possibly odontoblast cells on the surface of new skeletal growth.

Another aspect of the invention is to provide a formulation for therapeutic use which comprises a sufficient concentration of a compound of the invention and can be injected into the pulp of teeth, the space between the root of teeth and gum, or alveolar bone to prevent the damage on teeth and/or alveolar bone or regenerate the hard tissue in the damaged teeth and/or alveolar bone.

Another aspect of the invention is to provide toothpaste which comprises a sufficient concentration of a compound of the invention to enhance tooth and/or alveolar bone growth on areas where deterioration has occurred.

Yet another aspect of the invention is to provide a mouthwash which comprises a sufficient concentration of a compound of the invention to enhance tooth and/or alveolar bone growth on areas where deterioration has occurred.

Still another aspect of the invention is a dental floss having coated thereon and/or embedded therein a compound of the invention in an amount such that repeated application to teeth and/or alveolar bone results in enhanced tooth and/or alveolar bone growth on areas where deterioration has occurred.

An object of the invention is to provide a method of treating skeletal loss by the administration/application of any formulation/composition of the invention.

These and other objects, aspects, features and advantages will become apparent to those skilled in the art upon reading this disclosure.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a graph showing the relationship between bone mass and age in humans.

Figure 2 is a schematic drawing of a matrix extracellular phosphoglycoprotein wherein the area designated as "A" includes sequences which match peptides of the present invention and the area designated as "B" is a highly homologous motif to a group of bone-tooth matrix phosphoglycoproteins such as osteopontin (OPN), dentin sialophosphoprotein (DSPP), dentin matrix protein 1 (DMP1), and bone sialoprotein II (IBSP).

Figures 3A, 3B, 3C, and 3D are actual photographs of bone cross-sections (from a seven day mouse calvaria organ culture study) showing the effects of a control (Figure 3A),

fibroblast growth factor-1 (FGF-1) (Figure 3B), and two peptides of the invention designated D-00004 and D-00006 (Figure 3C and 3D, respectively).

Figure 4 is a graph comparing the effects of different compounds on calvaria.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before the peptides, analogs, formulations, and methodology of the present invention are described, it is to be understood that this invention is not limited to any particular embodiment described, as such may, of course, vary. It is also to be understood that the terminology used herein is with the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention which will be limited only by the appended claims.

Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limits of that range is also specifically disclosed. Each smaller range between any stated value or intervening value in a stated range and any other stated or intervening value in that stated range is encompassed within the invention. The upper and lower limits of these smaller ranges may independently be included or excluded in the range, and each range where either, neither or both limits are included in the smaller ranges is also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the invention.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described. All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited.

It must be noted that as used herein and in the appended claims, the singular forms "a", "and", and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a peptide" includes a plurality of such peptides and reference to "the method" includes reference to one or more methods and equivalents thereof known to those skilled in the art, and so forth.

The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates which may need to be independently confirmed.

DEFINITIONS

The terms "treat", "treating", "treatment" and the like are used interchangeably herein and mean obtaining a desired pharmacological and/or physiological effect. The effect may be prophylactic in terms of completely or partially preventing a disease or symptom thereof and/or may be therapeutic in terms of partially or completely curing a disease and/or adverse effect attributed the disease such as enhancing the effect of vitamin D. "Treating" as used herein covers treating a disease in a vertebrate and particularly a mammal and most particularly a human, and includes:

(a) preventing the disease from occurring in a subject which may be predisposed to the disease but has not yet been diagnosed as having it;

(b) inhibiting the disease, i.e. arresting its development; or

(c) relieving the disease, i.e. causing regression of the disease.

The invention is particularly directed towards peptides which make it possible to treat patient's which have experienced bone loss or which would be expected to experience bone loss and thus is particularly directed towards preventing, inhibiting, or relieving the effects of bone loss. A subject is " treated" provided the subject experiences a therapeutically detectable and beneficial effect which may be measured based on a variety of different criteria including increased bone growth, increased bone strength or other characteristics generally understood by those skilled in the art to be desirable with respect to the treatment of diseases related to bone.

The term "antibody" is meant an immunoglobulin protein capable of binding an antigen. The term "antibody" as used herein is intended to include antibody fragments (e.g. $F(ab')_2$, Fab', and Fab) capable of binding an antigen or antigenic fragment of interest.

The term "binds specifically" is meant high avidity and/or high affinity binding of an antibody to a specific peptide -- specifically a peptide of the invention. Antibody binding to its specific target epitope is stronger than the binding of the antibody to other epitopes on the peptide or to other epitopes on other peptides. Antibodies which bind specifically to a

peptide of interest may be capable of binding to other peptides at a weak, yet detectable level (e.g. 10% or less of the binding shown to the peptide of interest). Such weak binding or background binding, is readily discernable from the specific antibody binding to the peptide of interest, e.g. by the use of appropriate controls.

The term "skeletal loss" refers to any situation in which skeletal mass, substance or matrix or any component of the skeleton, such as calcium and phosphate, is decreased or the bone is weakened such as in terms of its ability to resist being broken.

The term “skeleton” includes both bone and teeth. In the same manner, the term “skeletal” means both bone and teeth.

The term "osteoporosis" is intended to refer to any condition involving bone loss, i.e. involving a reduction in the amount of bone mass or substance resulting from any cause. The term particularly results in a bone loss resulting from demineralization of the bone, post menopausal or peri-menopausal estrogen decrease or nerve damage.

The term "subject" refers to any vertebrate, particularly any mammal and most particularly including human subjects.

INVENTION IN GENERAL

A compound of the invention is a peptide comprising from 10 to 50 amino acids. The amino acids are preferably one of the twenty naturally occurring L-amino acids. However, D-amino acids may be present as may amino acid analogs. A sequence of the invention will comprise an integrin binding motif such as RGD sequence in either the L- or D-form but preferably in the L-conformation. The peptide of the invention can be amidated or non-amidated on its C-terminus, or carboxylated or non-carboxylated on its N-terminus. The peptide of the invention may or may not contain a glycosaminoglycan binding motif such as SGDG sequence in L- or D-isomer form. A compound of the invention is still further characterized by biological activity i.e. it enhances skeletal growth as well as the growth or recruiting of osteoblast or odontoblast cells on surface of the new skeletal growth.

Specific examples of peptides of the invention comprise seven to forty-seven amino acids on either side of the RGD sequence of the naturally occurring sequence of matrix extracellular phosphoglycoprotein. Thus, examples of peptides of the invention comprising sequences taken from the following sequence and including the RGD sequence shown in bold:

DSQAQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFEGSGYTDLQE**RGD**NDISPFSGD
GQPFKDIPGKGEATGPDLEGKDIQTGFAGPSEAESTHL

Specific examples of peptides of the invention which comprise the RGD sequence as the terminal sequence include the following:

AQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFEGSGYTDLQE**RGD**
RGDAQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFEGSGYTD**RGD**
RGDSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFEGSG**RGD**
RGDTHRIQHNIDYLKHLSKVKKIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPSDFE**RGD**
RGDLKHLSKVKKIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNIDYLKHLSKVKKIPS**RGD**
RGDLSKVKKIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNIDYLKHLSK**RGD**
RGDVKKIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNIDYLK**RGD**
RGDIPSDFEGSGYTDLQE
DSQAQKSPVKSKSTHRIQHNID**RGD**
RGDDFEGSGYTDLQE
DSQAQKSPVKSKSTHR**RGD**
RGDGSGYTDLQE
DSQAQKSPVK**RGD**
RGDGYTDLQE
DSQAQKS**RGD**
RGDNDISPFSGDGQPFKDIPGKGEATGPDLEGKDIQTGFA

Specific examples of the peptides of the invention which comprise the RGD internally include the following:

NDI **RGD**SPFSGDGQPFKDIPGKGEATGPDLEGKDIQTGFA

NDISPF **RGD**SGDGQPFKDIPGKGEATGPDLEGKDI

NDISPFSGD **RGD**GQPFKDIPGKGEATGPDL

FSGDGQPFKDIPGKGEATGPDLEGKDIQTGFAGPSEAES **RGD**THL

IPGKGEATGPDLEGKDIQTGFAGPSE **RGD**AESTHL

EATGPDLEGKDIQTGFAG **RGD**PSEAESTHL

NDISPFSGDGQPFKD **RGD**IPGKGEATGPDLEGK

GKGEATGPDLEGKDI **RGD**QTGFAGPSEAESTHL

FSGDGQPFKDIPGKGEATG **RGD**PDLEGKDIQTGFAGPSEA

DGQPFKDIPGKGEATG **RGD**PDLEGKDIQTGF

PFKDIPGKGEATG **RGD**PDLEGKDIQ

DIPGKGEATG **RGD**PDLEGKDIQTGFAGP

DGQPFKDIPGKGEATG **RGD**PDLEGKDIQTGF

GKGEATG **RGD**PDLEGKDIQTGFAGPSEA

EATG **RGD**PDLEGKDIQTGF

EATG **RGD**PDLEGK

EATG **RGD**PDL

All or any of the amino acids in the above sequences may be in the D- or L-conformation and may be substituted with equivalent analogs. The preferred embodiments comprise naturally occurring amino acids in the L-conformation.

All or any of the above sequences may be amidated or non-amidated on their C-terminus, or carboxylated or non-carboxylated on their N-terminus.

Matrix extracellular phosphoglycoprotein was cloned and characterized from a human tumor that caused osteomalacia in the patients. This extremely rare type of tumor called Oncogenic Hypophosphatemic Osteomalacia (OHO) tumor has been known to cause renal phosphate leak, hypophosphatemia (low serum phosphate levels), low serum calcitriol (1,25-vitamin D3), and abnormalities in skeletal mineralization (Osteomalacia). In the patients of OHO tumor, resection of the tumors results in remission of all of the above symptoms and it has been proposed that a circulating phosphaturic factor secreted from OHO tumor plays a role in osteomalacia. Matrix extracellular phosphoglycoprotein was proposed as a candidate of this phosphaturic factor phosphoglycoprotein (Rowe et. al., Genomics (2000) 67:56-68).

09547037.081502

Phosphate plays a central role in many of the basic processes essential to the cell and the mineralization of skeleton. In particular, skeletal mineralization is dependent on the regulation of phosphate and calcium in the body and any disturbances in phosphate-calcium homeostasis can have severe repercussions on the integrity of bone. In the kidney, phosphate is lost passively into the glomerular filtrate and is actively reabsorbed via a sodium (Na+) dependent phosphate cotransporter. In the intestine, phosphate is absorbed from foods. A sodium (Na+) dependent phosphate cotransporter was found to be expressed in the intestine and recently cloned (Hilfiker, PNAS 95(24) (1998), 14564-14569). The liver, skin and kidney are involved in the conversion of vitamin D3 to its active metabolite, calcitriol, which plays an active role in the maintenance of phosphate balance and skeletal mineralization.

Vitamin D deficiency causes rickets in children and osteomalacia in adults. Both conditions are characterized by failure of calcification of osteoid, which is the matrix of skeleton.

Thus, all of the humoral functions by matrix extracellular phosphoglycoprotein, namely, renal phosphate leak, hypophosphatemia (low serum phosphate levels), low serum calcitriol (1,25-vitamin D3), are harmful to healthy skeletal formation.

Matrix extracellular phosphoglycoprotein is a large polypeptide with 525 amino acid with short N-terminus signal sequence. Therefore, it is highly probable that this molecule is secreted from its producing cells into the body fluid and circulation. Out of its 525 amino acid sequence, 23 amino acid motif on the C-terminus showed high similarities to a group of bone-tooth mineral matrix phosphoglycoproteins such as osteopontin (OPN), dentin sialophosphoprotein (DSPP), dentin matrix protein 1 (DMP1), and bone sialoprotein II (IBSP). It has been proposed that these bone-tooth mineral matrix phosphoproteins may play important roles in skeletal mineralization.

Notwithstanding the above observations about matrix extracellular phosphoglycoprotein, smaller peptide sequence containing integrin binding motif that is located within the amino acid sequence and far from its C-terminus sequence with a high degree of similarity to other bone-tooth mineral matrix phosphoglycoproteins demonstrated a very potent skeletal formation activity and increased the number of osteoblasts on such skeletal formation surface. The potency of such activities was equivalent to fibroblast growth factor (FGF). It was surprising in that small motifs within a large protein which protein has destructive functions on the skeleton demonstrated potent bone formation activity, and that

09647037.081600

such motifs were located far from the sequence which showed homology to other known bone-tooth matrix proteins.

Another surprising fact was that potent skeletal formation motifs of the invention contained an integrin binding motif, in particular, RGD sequence. It has been reported that a synthetic peptide containing the RGD sequence inhibited bone formation and resorption in a mineralizing organ culture system of fetal rat skeleton (Gronowicz et. al. Journal of Bone and Mineral Research 9(2):193-201 (1994)), that is a very similar experimental method used to test the subject of the present invention.

Further, the skeletal formation activity provided by the small peptides of the invention was as potent as that of an intact growth factor such as FGF.

EXAMPLES

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the present invention, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (e.g. amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is weight average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

EXAMPLE 1

Synthesis of D-00001, etc.

Six different peptides were manually synthesized by the 9-fluorenylmethoxycarbonyl (Fmoc) strategy and prepared in the C-terminal amide form. The six peptides are as follows:

D-00001:	IPSDFEGSGYTDLQE
D-00002:	DFEGSGYTDLQE**RGD**
D-00003:	YTDLQE**RGD**NDISPF
D-00004:	E**RGD**NDISPFSGDGQ
D-00005:	NDISPFSGDGQPFKD
D-00006:	TDLQE**RGD**NDISPFSGDGQPFKD

(C-terminus amidated)

Amino acid derivatives and resins were purchased from Bachem, Inc., Torrance, CA., and Novabiochem, La Jolla, CA. The respective amino acids were condensed manually in a stepwise manner using 4-(2', 4'-dimethoxyphenyl-Fmoc-aminomethyl)-phenoxy resin. N-methyl pyrrolidone was used during the synthesis as a solvent. For condensation, diisopropylcarbodiimide/N-hydroxybenzotriazole was employed, and for deprotection of N^{α}-Fmoc groups, 20% piperidine in N-methyl pyrrolidone was employed. The following side chain protecting groups were used: Asn and Gln, trityl; Asp, Glu, Ser, and Thr, t-butyl; Arg, 2,2,5,7,8-pentamethylchroman-6-sulfonyl; and Lys, t-butoxycarbonyl. Resulting protected peptide resins were deprotected and cleaved from the resin using a trifluoroacetic acid-thioanisole-*m*-cresol-ethanedithiol-H_2O (80:5:5:5:5, v/v) at 20°C for 2 h. Resulting crude peptides were precipitated and washed with ethyl ether then purified by reverse-phase high performance liquid chromatography (using Vydac 5C18 column and a gradient of water/acetonitrile containing 0.1% trifluoroacetic acid). All peptides were obtained with 5-20% yield (from the starting resin). Purity of the peptides was confirmed by analytical high performance liquid chromatography. Identity of the peptides was confirmed by a Sciex API IIIE triple quadrupole ion spray mass spectrometer.

EXAMPLE 2

Fetal Mouse Calvarial Assay

Reagents

FGF-1 was purchased from Peprotech Inc. (Rocky Hill, NJ). RGD-1, 2, 3, 4, 5 and 6 (referred to here as D-00001, D-00002, D-00003, D-00004, D-00005 and D-00006) were provided by Dr. Nomizu (Hokkaido University, Japan).

Mice

Pregnant ICR mice were purchased from SLC Japan Co. Ltd. (Shizuoka, Japan).

Mouse calvarial organ culture

Mouse calvarial organ culture was performed as described in Mundy G et al. *Science* 286: 1946-1949, 1999 and Traianedes K et al. *Endocrinology* 139: 3178-3184, 1998. The calvaria from 4-days-old mice were excised and cut in half along the sagittal suture. Each half of the calvaria was placed on a stainless steel grid in a 12-well tissue culture dish (Asahi Glass Techno Corp.,

Funabashi, Japan). Each well contained 1.5 ml of BGj medium (Sigma, St. Louis, MO) supplemented with 0.1% bovine serum albumin (Sigma) and each compound. FGF-1 was used as a positive control as described by Mundy et al. The medium was changed at day 1 and 4, and the assay was terminated at day 7.

Histomorphometrical analysis

Calvaria was fixed with 10% neutral-buffered formalin, decalcified with 4.13% EDTA and embedded in paraffin. 4mm-thickness sections were made and stained with hematoxylin and eosin. New bone area was measured using Image-Pro Plus (Media Cybernetics, Silver Spring, MD).

The six peptides of Example 1 were tested for their ability to enhance bone growth with the tests being carried out as described above in Example 2. The peptides which did not include the RGD sequence did not show positive results. The other four peptides showed positive results with the best results being obtained with the sequences

D-00004: E**RGD**NDISPFSGDGQ, and

D-00006: TDLQE**RGD**NDISPFSGDGQPFKD.

The best results are in Figure 3 (specifically Figure 3C and 3D). Data from these results are graphically shown in Figures 4.

While the present invention has been described with reference to the specific embodiments thereof, it should be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation, material, composition of matter, process, process step or steps, to the objective, spirit and scope of the present invention. All such modifications are intended to be within the scope of the claims appended hereto.